Report No. UT-03.30

TRAFFIC DETECTOR SELECTION PROCEDURE

(GUIDELINE DRAFT)

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UDOT RESEARCH & DEVELOPMENT REPORT ABSTRACT

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16. Abstract

Traffic detection systems provide high quality real time and historical traffic data for a variety of traffic applications. Inductive loops, though they are the most widely deployed detector technology, have some limitations. They disrupt traffic flow during installation and maintenance, fail at a high rate under particular conditions, and are inflexible. Professionals are seeking alternative technologies to replace inductive loops.

A large number of traffic detector devices with different operation theories are currently available on the market. Manufacturers are constantly improving detector performance and capabilities. No single detector device is best for all applications. Each has its limitations, specializations, and individual capabilities. Because such a diversity of detector technologies and devices exists, it may be problematic to select the optimal detector technology and particular device to meet specific project requirements. To a large extent, successful application of detector technologies depends on proper device selection.

This guideline provides a systematic method for selecting detectors for permanent applications. The selection method considers many factors, including data type, data accuracy (within different environmental and traffic conditions), ease of installation and calibration, cost, reliability, and maintenance. A variety of detector technologies and devices are compared using these factors in order to help the user choose the best technology and device for his or her purposes. This guideline provides comparison matrixes for detector technologies and for specific detector devices. The technology matrixes provide general information about each detector technology, and the device matrixes offer specific information regarding each particular detector device. The matrixes need to be continuously updated to reflect new changes in the detector field.

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1. INTRODUCTION

Traffic detection systems provide high quality real time and historical traffic data for a variety of traffic applications. Inductive loops, though they are the most widely deployed detector technology, have some limitations. They disrupt traffic flow during installation and maintenance, fail at a high rate under particular conditions, and are inflexible. Professionals are seeking alternative technologies to replace inductive loops.

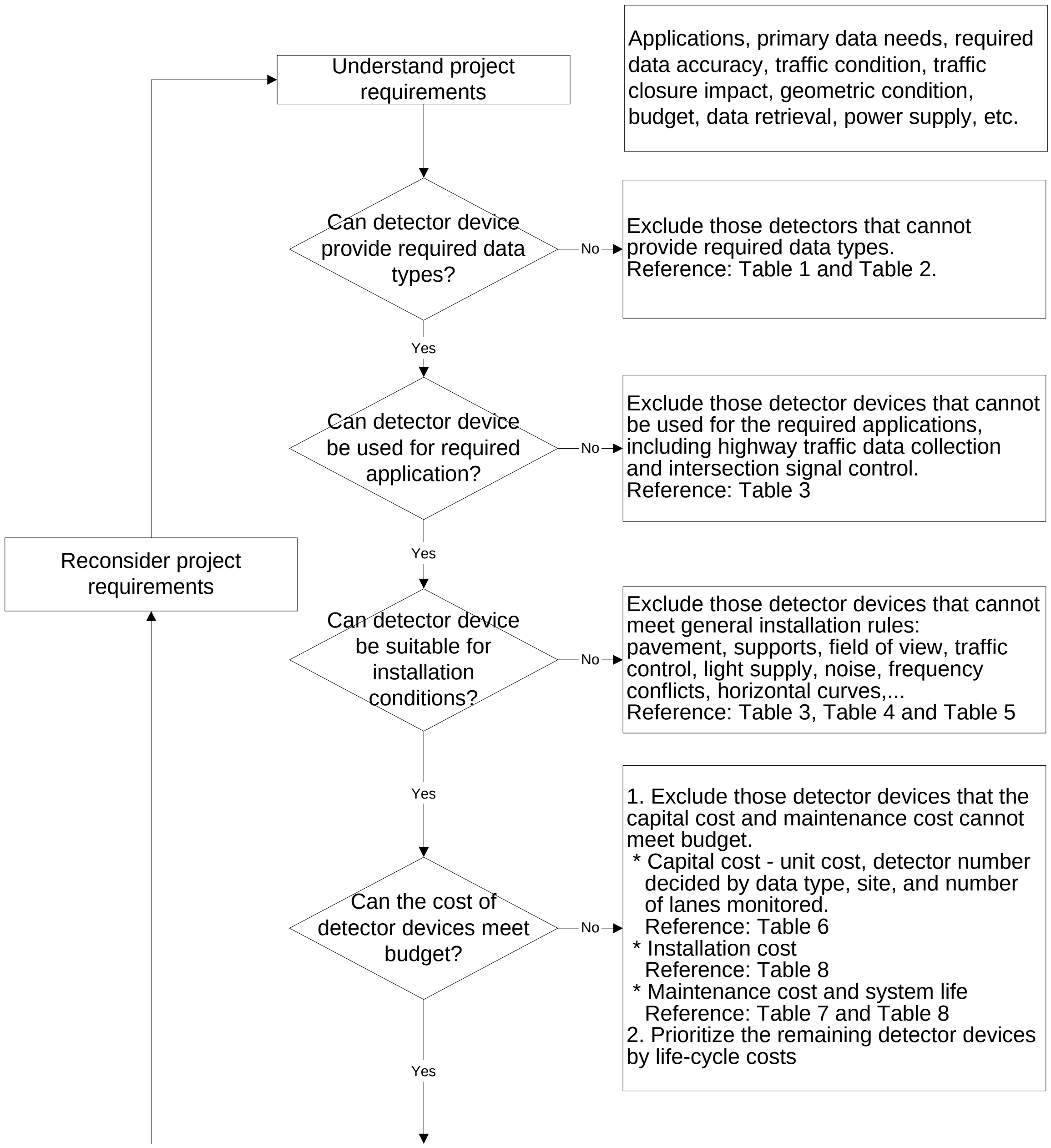
A large number of traffic detector devices with different operation theories are currently available on the market. Manufacturers are constantly improving detector performance and capabilities. No single detector device is best for all applications. Each has its limitations, specializations, and individual capabilities. Because such a diversity of detector technologies and devices exists, it may be problematic to select the optimal detector technology and particular device to meet specific project requirements. To a large extent, successful application of detector technologies depends on proper device selection.

This guideline provides a systematic method for selecting detectors for permanent applications. The selection method considers many factors, including data type, data accuracy (within different environmental and traffic conditions), ease of installation and calibration, cost, reliability, and maintenance. A variety of detector technologies and devices are compared using these factors in order to help the user choose the best technology and device for his or her purposes. This guideline provides comparison matrixes for detector technologies and for specific detector devices. The technology matrixes provide general information about each detector technology, and the device matrixes offer specific information regarding each particular detector device. The matrixes need to be continuously updated to reflect new changes in the detector field.

The technologies discussed in this guideline are inductive loop, magnetic, active infrared, passive infrared, microwave radar, ultrasonic, passive acoustic, and Video Image Processing (VIP).

2. TRAFFIC DETECTION SELECTION FOR PERMANENT APPLICATIONS

Figure 1 shows the traffic detector selection procedure for permanent applications.



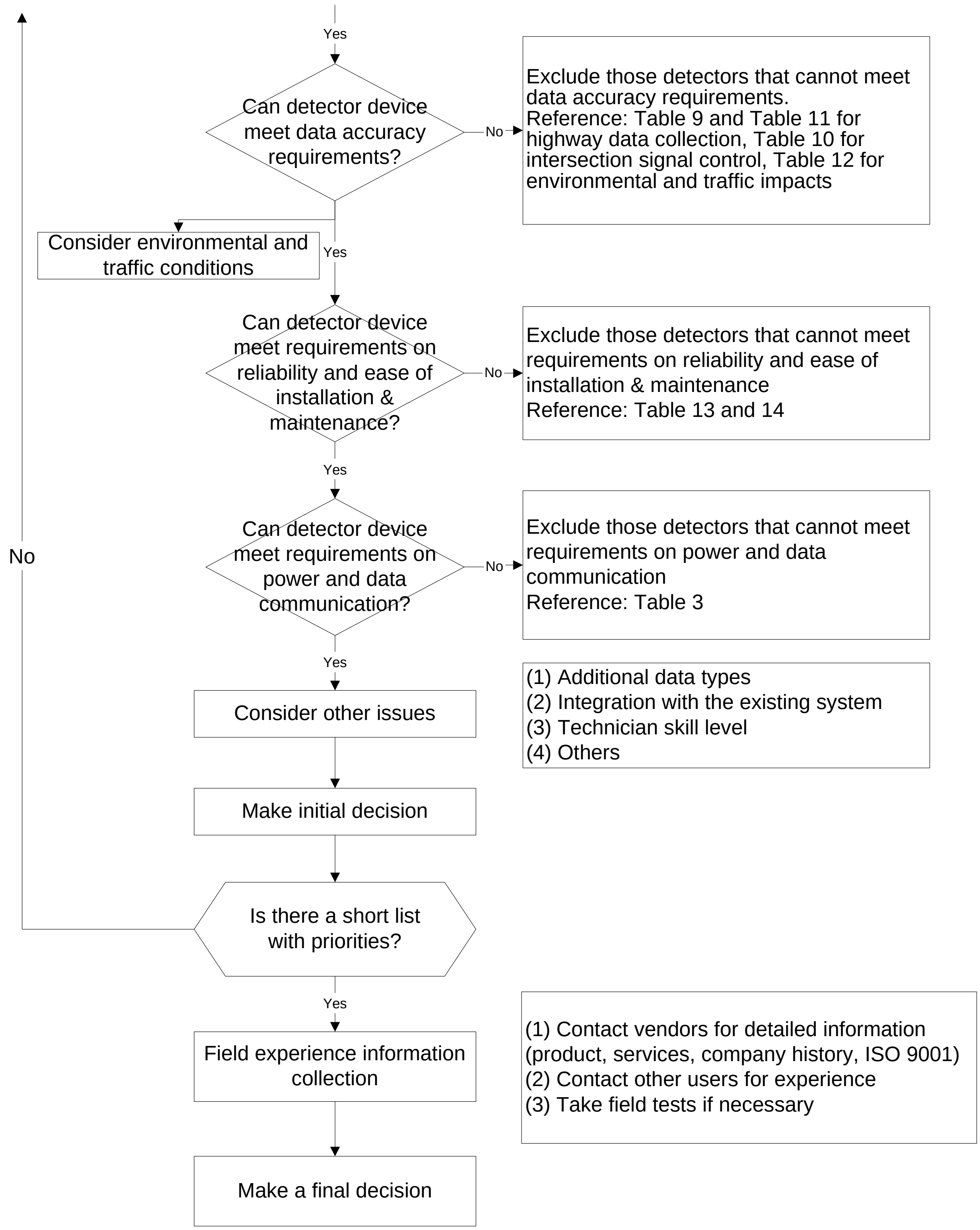


Figure 1: Traffic Detector Selection Procedure for Permanent Applications

2.1 Understand Project Requirements

Before going through the selection procedure, it is necessary to understand the requirements and conditions of the project for which the traffic detection system will be used. Several questions should be answered in advance:

1. What are application detectors used for?

- Highway traffic data collection
- Intersection signal control

2. What are primary data needs?

- Count
- Speed
- Occupancy
- Presence
- Classification (axle or length)
- Others

3. What is the detection accuracy level required for the specific project?

4. What is the budget for the project?

- Capital budget (device and installation)
- Maintenance budget

5. Are there stop-and-go traffic conditions at application sites?

6. Is it possible to close traffic lanes for installation and what impact will installation have on traffic flow?

7. Is the temperature at the site frequently extremely hot or cold? Are there often heavy snow, rain, fog, and/or wind?

8. Are there supportive infrastructures at application sites? Are they overhead or sidefire? What are the maximum heights?

9. Is the pavement in good condition? Has there been a recent pavement rebuild plan?

10. What are the geometric conditions of application sites? It is beneficial to have a geometric sketch map for application sites.

11. What are the requirements of data communication and data storage?

12. What are the requirements of data aggregation?

13. Are there any other requirements from existing traffic systems?

2.2 Select by Data Type

Exclude those detector technologies and detector devices that cannot provide required data types. Table 1 and Table 2 provide reference information.

Five primary data types measured by detectors are count, speed, presence, occupancy, and classification. Vehicle classification is based on vehicle length and/or height. VIP systems can provide additional data in the categories of density, queue length, headway and incident number. Vehicle probes can directly measure travel time, but travel time can also be calculated from average speed, which is inversely proportional to travel time. Detector devices typically have varied interval settings for data aggregation, such as twenty-second, five-minute, and fifteen-minute settings.

2.3 Select by Applications

Exclude those detector devices that cannot be used for the required applications. Table 3 provides reference information.

Two primary detector applications are highway traffic data collection and intersection signal control. Highway traffic data collection typically detects traffic flow, speed, occupancy and classification. Vehicle presence is the primary data for traffic signal control; speed is needed for dilemma zone protection. Traffic signal control requires higher data accuracy, as undetected vehicles may result in signal violation and accident consequence.

2.4 Select by General Installation Conditions

Aside from experience and product manual information, there are some general rules to follow regarding detector applications:

1. Poor pavement is not suitable for intrusive detectors.

2. Inductive loops cannot be installed at some sites, including bridge decks and railroad crossings.

3. Horizontal curves can create a problem for inductive loops when vehicles do not travel in the center of a lane.

4. Application sites should have supportive infrastructures if considering non-intrusive detectors. Otherwise, the necessary supportive infrastructures should be counted into the capital costs.

5. Installation sites should have good fields of view for non-intrusive detectors. No obstacles should exist between detectors and detection zones.

6. Most non-intrusive detectors commonly require installation within certain heights and offset distances (for sidefire installation) to perform at their best. Make sure that selected installation sites meet the requirements of installation. Table 6 provides reference information. Table 4 provides the minimum camera height needed to reduce the adjacent-lane occlusion of VIP detector signal control applications.

7. Consider the impacts of closing traffic lanes for installation and the potential costs for the closure at application sites. This will influence decisions regarding whether to use intrusive or non-intrusive detectors and whether to use overhead installation or sidefire installation for non-intrusive detectors.

8. VIP detectors need streetlights in order to work properly at night, so VIP application sites should have an adequate light supply.

9. VIP detectors should be cautiously used to provide dilemma zone protection (12,15). Table 5 provides minimum camera height for advanced detection of VIP detectors.

10. Acoustic noise in the audible or ultrasonic ranges can interfere with the operation of acoustic and ultrasonic detectors. The installation sites should have no acoustic noise and relatively small and focused fields of view should be used to reduce the impacts.

11. When the same frequency as SPVD (Wireless data transmission on 47MHz) exists in the installation area, it may result in intermittent "false calls." Therefore, it is necessary to determine whether the particular frequency is already in use in the area by another entity.

12. Electromagnetic interference may occur when microwave radar detectors operate in the sites where other radar waves transmit at close frequencies. Microwave radar frequencies are regulated to be near 10.5, 24.0 or 34.0 GHz.

13. Sidefire calibration is difficult for passive infrared.

2.5 Select by Project Budgets and Cost Comparison

Capital cost

Capital cost is dependent on unit device cost and on the quantity of devices used. Data type and geometric conditions determine the number of devices needed. Using intrusive detectors to collect speed commonly requires dual configuration. A typical intersection site requires that four approaches be monitored while a typical freeway site requires that only two approaches be monitored. To monitor multiple lanes, multiple-lane detector technologies are commonly used because of their low device cost, ease of installation and maintenance, and high reliability. Single-zone multiple-lane detectors are limited to monitoring a zone composed of several lanes without lane discrimination while multiple-zone detectors can cover several zones simultaneously.

Table 6 provides reference information.

Installation cost

Installation cost is relative to the material used in installation and the ease of installation and calibration. Traffic control cost should be considered for detector technologies that require lane closures during installation as traffic control for a single lane closure can cost one thousand to fifteen thousand dollars in large urban areas (8). The actual average installation cost may be similar for devices with similar difficulties of installation and calibration.

Table 8 provides reference information.

Maintenance cost

Because the application periods of most non-intrusive detectors are short, the average maintenance cost related to long-term performance is difficult to obtain. Table 7 provides reference information with estimated values.

Life cycle cost

Life cycle cost is also dependent on system life – the longer the system life of a detector device, the lower the life cycle cost. Table 8 provides the system life of each detector technology.

Exclude detector devices when their capital cost and maintenance cost are not within budget.

Make a priority list on remaining detector devices by life cycle costs. The following equation is used to calculate life cycle cost:

$$LifeCycleCost = ((DeviceCost * Quantity) + InstallationCost)\left[\frac{i(1+i)^{OY}}{(1+i)^{OY}-1}\right] + AnnualMa\mathrm{int}\,enanceCost$$

Where:

LifeCycleCost = Life-cycle cost, ($)

DeviceCost = Unit device cost, ($)

Quantity = the quantity of devices required for the application,

OY = Operation year, which can be system life or designed operation life, (year)

InstallationCost = Installation cost, including labor, materials, etc. ($)

AnnualMaintenanceCost = Annual maintenance cost ($/year).

Estimated life cycle costs of detector devices for a typical freeway application and a typical intersection application are shown in Tables 15 and 16.

Other cost issues, including quantity discount and pavement rebuild plans, should be considered. A quantity discount is often associated with a large number of units purchased. James Bonneson et. al (15) mentioned that at a typical intersection, when the pavement will be reconstructed in less than three years, the replacement of all inductive loops will exceed the cost of installing the VIP detectors.

2.6 Select by Data Accuracy

Data detection accuracy should be within error tolerances. Field test results by third parties can provide reference information on data accuracy.

Tables 9 and 11 show highway traffic data collection.

Table 10 shows intersection signal control. Several detector technologies, including inductive loop, magnetic, true-presence microwave radar, passive infrared, ultrasonic, and VIP systems, are used for intersection signal control.

Detection accuracy is affected by environmental and traffic conditions. Primary environmental factors are precipitation, wind, temperature, and shadow and light. Rain and snow can reduce visibility and may also hinder the short-length wave produced by infrared and other detectors. Wind may change the detector position or cause detector vibration, especially when detectors are installed near the end of the mast arm or high pole. The movement can reduce the accuracy of detection. And, extremely low or high temperature can reduce the accuracy of some detectors. The VIP detectors may suffer from poor light, sunlight, vehicle headlight reflection, and shadows caused by buildings or vehicles. High traffic volume can cause stop-and-go congestion and low vehicle speed and can lead to poor detection by some detector technologies. Table 12 provides information about environmental and traffic impacts on detector performance.

2.7 Select by Reliability and Ease of Installation & Maintenance

Tables 13 and 14 provide reference information.

2.8 Select by Power and Data Communication

Power requirements are of most concern in remote areas where power sources are unavailable. Table 3 provides reference information.

2.9 Select by Other Issues

Projects should also consider the following issues in addition to other project-specific issues:

1. The detector devices' provision of additional data types.
2. The detection system's ability to integrate with existing systems.
3. The skill level of maintenance personnel.
4. Capability for wireless data communication.
5. Capability for remote adjustment of calibration parameters and for trouble-shooting.

2.10 Make Initial Decision

If after following the selection steps no detector devices remain, project requirements should be reconsidered and possibly altered. If several options remain, a priority list should be made and the detector options reconsidered.

2.11 Field Information Collection

To select the best detector for their purposes, buyers should contact vendors for detailed information, contact other users for experience, and conduct field tests if necessary. Vendors can provide detailed information about products and company services. It is important to know a company's history in order to ensure that it has a good reputation and a commitment to the industry. This minimizes the risk that a product will be abandoned shortly after an agency invests in it. Buyers should ensure that the company has an ISO 9001 certification, or credentials that a manufacturer has implemented a process of constant improvement and has the maturity to reliably manufacture products. Finally, the warranty period of a detector device should also be considered.

It is strongly recommended that a field test be carried out to guarantee that a detector is appropriate for a project. In addition, manufacturers may be unaware of or reluctant to discuss certain aspects of their products, so it is wise to contact actual users about their experience prior to purchasing a new device. Although products are continuously being improved, they may show problems in field tests. Buyers should pay close attention to recurring problems and ask vendors how they should deal with these problems.

2.12 Make a Final Decision

The preceding steps will help buyers narrow their detector device selection and select the product appropriate for their needs.

3. REFERENCE TABLES

Table 1: Data Types of Detector Technologies

Detector Type			Volume/Count	Speed	Classification	Occupancy	Presence
I	Inductive Loop		✓	✓[1]	✓[2]	✓	✓
	Magnetic		✓	✓[3]	✓[3]	✓	✓
N	Active Infrared		✓	✓	✓	×	×
	Passive Infrared		✓	✓[4]	✓	✓	✓
	Microwave Radar	Doppler	✓	✓	✓	✓	
		True Presence	✓	✓	✓	✓	✓
	Ultrasonic		✓	×	×	×	✓
	Passive Acoustic		✓	✓	✓	✓	✓
	Video Image Processing		✓	✓	✓	✓	✓

Note:
(1) – Speed can be measured by using dual-loops with a known distance apart, or by algorithms with a single-loop covering the length of the detection zone and vehicle.
(2) – Advanced detector cards using "vehicle signature" can measure Classification.
(3) – Speed and classification measurement by magnetic detectors requires two units.
(4) – Passive infrared detectors with multi-detection-zone capability can measure speed.
✓ - Can provide the data type, × - Cannot provide the data type.

Table 2: Data Types of Detector Devices

Device	Volume	Speed	Classification (length)	Occupancy	Presence	Other data
Inductive Loop	✓	✓[(1)]	✓[(2)]	✓	✓	
Magnetic						
3M Microloop	✓	✓[(3)]	✓[(3)]	✓	✓	
SPVD	✓	✓[(3)]	×	✓	✓	
Passive Infrared						
ASIM IR 224	✓	×	×	×	✓	
ASIM IR 254	✓	✓	✓	✓	✓	
Eltec Model 842	×	×	×	×	✓	Vehicle speed < 45 mph
Siemens PIR-1	✓	×	×	✓	✓	Queue
Active Infrared						
Autosense II	✓	✓	✓	×	×	Lane position
Microwave Radar – Doppler						
TC 26-B	✓	✓	×	×	×	
TDN-30	✓	✓	×	×	×	
Loren	✓	✓	✓	✓	×	Counting system required to capture data
Microwave Radar – True Presence						
Accuwave 150LX	✓	×	×	×	✓	
RTMS	✓	✓	✓	✓	✓	Headway
Ultrasonic						
TC-30	✓	×	×	×	✓	
Lane King	✓	×	×	×	✓	
Passive Acoustic						
SmarTek SAS-I	✓	✓	✓	✓	✓	
SmartSonic TSS-1	✓	×	✓	×	×	
Video Image Processing						

Autoscope	✓	✓	✓	✓	✓	Time headway, density, space occupancy, space mean speed, level of service, turning movement, incident
VideoTrak	✓	✓	✓	✓	✓	Density, headway, delay, queue length, incident
Traficon	✓	✓	✓	✓	✓	Headway, gap, length, density, queue, incident
Vantage	✓	✓	✓	✓	✓	Headway, gap, length, incident
Traffic Vision	✓	✓	✓	✓	✓	Lane changes, queue, turns, headway, incident

Note:
(1) – Speed can be measured by dual-loops with a known distance apart, or by algorithms with a single-loop covering the length of the detection zone and vehicle.
(2) – Advanced detector cards using “vehicle signature” can measure Classification.
(3) – Requires two units.
✓ - Can provide the data type, × - Cannot provide the data type.

Table 3: Other Detector Device Issues

Technology/ Sensor	Traffic Data Collection/ Signal Control	Supply Voltage	Communication	Data Storage
Inductive loop	Both	< 30VDC		
Magnetic				
3M Microloop	Both	Powered off amplifier 10.8v – 39v	Dual communications – front panel to laptop or modem or pin 19-21 off back panel	16K additional memory available
SPVD	SC	Detector: 13.5V 17Ah battery pack; Receiver: 10 –25VDC	Wireless data transmission on 47MHz	None
Active Infrared				
Autosense II	TDC	?	RS232/RS422	?
Passive Infrared				
ASIM IR 224	SC	AC: 500mW DC: 35mA@12VDC	RS232	None
ASIM IR 254	Both	8mA@12VDC	RS485	20 vehicles
Siemens PIR-1	Both	115VAC 10.5-26VDC	?	?
Eltec Model 842	SC	95-135VAC	N/A, relay output	None
Microwave Radar				
Accuwave 150LX	SC	95-125VAC	RS232	?
RTMS	Both	12-14VDC	RS232/RS485	?
TC 26B	TDC	12-24VDC/AC	?	?
TDN-30	TDC	12-14VDC	RS232	?
Loren	TDC	?	RS232	?

Ultrasonic				
Lane KingTM	SC	115±20VAC	RS422/RS485	?
TC-30	SC	12-24VAC/DC	?	?
Passive Acoustic				
SmartSonic TSS-I	Rural road data collection (a free flow road with speeds greater than 35 mph)	12VDC with solar charging or AC power	RS232	64K memory
SmarTek SAS – I	Both	0.125 mA at 12 VDC (1.5 watts)	RS-232 or RS-422, Ethernet, opto-isolated relay	60 days storage of 5 lanes of data
Video Image Processing				
Autoscope 2004[(1)]	Both	115/230VAC	RS232/RS485/RJ45	?
Autoscope solo	Both	24VAC, 12-18VDC	RS485	?
VideoTrak 900[(1)]	Both	Camera 110V-40W max dissipation, four camera unit draws quiescent current of 0.5 amp	RS232/RS485	4MB memory
Traficon	Both (different VIP detector cards)	10.8-26.5VDC	RS232/RS485/RJ45	VIP/presence: 10 days VIP/data: 4 days

Note:
(1) – Autoscope 2004 is being replaced by the new version Autoscope 2020; VideoTrak 900 is being replaced by a new version.
TDC – Highway Traffic Data Collection, SC – Intersection Signal Control.

Table 4: Minimum Camera Height to Reduce Adjacent-Lane Occlusion

Camera Location	Lateral Offset(1), feet	No Left-turn Lanes			One Left-turn Lane			Two Left-turn Lanes		
		Through+Right Lanes(2)			Through+Right Lanes(2)			Through+Right Lanes(2)		
		1	2	3	1	2	3	1	2	3
		Minimum Camera Height(3,4), feet								
Left Side of Approach	-75	54	50	45	59	54	50	63	59	54
	-65	47	42	38	51	47	42	56	51	47
	-55	39	35	30	44	39	35	48	44	39
	-45	32	27	23	36	32	27	41	36	32
	-35	24	20	20	29	24	20	26	21	20
	-25	20	20	20	21	20	20	26	21	20
	-15	20	20	20	20	20	20	20	20	20
	-5	20	20	20	20	20	20	20	20	20
Center	0	20	20	20	20	20	20	20	20	20
Right Side of Approach	5	20	20	20	20	20	20	20	20	20
	15	20	20	20	20	20	23	20	20	20
	25	20	20	20	21	26	30	20	21	26
	35	20	20	20	29	33	38	24	29	33
	45	20	20	20	36	41	45	32	36	41
	55	20	20	20	44	48	53	39	44	48

Note:
(1) – Lateral offset of the camera measured from the center of the approach traffic lanes, including turn lanes. Cameras to the left of the center have a negative offset.
(2) – Total number of through and right-turn lanes on the approach.
(3) – Based on a vehicle height of 4.5 feet and a vehicle width of 6.0 feet.
(4) – Underlined values in each column correspond to typical lateral offsets when the camera is mounted within ten feet of the edge of the traveled way.

Source: Video Detection For Intersection and Interchange Control (15).

Table 5: Minimum Camera Height for Advance Detection

Distance Between Camera and Stop Line[(1)], feet	Approach Speed Limit[(2)], mph			
	45	**50**	**55**	**60**
	Minimum Camera Height[(3)], feet			
50	24	26		
60	24	27		
70	25	27		
80	25	28	30	32
90	26	28	31	33
100	27	29	31	34
110	27	30	32	34
120	28	30	32	35
130	28	31	33	35
140	29	31	34	36
150	30	32	34	36
Distance to Furthest Zone[(4)], feet	353	392	431	470

Note:
(1) – Distance between the camera and the stop line, as measured parallel to the direction of travel.
(2) – Approach speed limit is assumed to equal the eighty-fifth percentile speed.
(3) – Based on distance-to-height ratio of 17:1.
(4) – Distances based on 5.0 seconds travel time at the ninety-fifth percentile speed.

Source: Video Detection For Intersection and Interchange Control (15).

Table 6: Cost Comparison of Detector Devices

Technology/Sensor	Device cost	Lanes	Mounting
Inductive loop	$500-$1000/loop (including installation)	S	Under pavement
Magnetic			
3M Microloop	Canoga Detector C822F(2 channel): $546; Canoga Detector C824F (4 channel): $704; 702 Microloop Probe: $160; 701 Microloop Probe: $138; Installation Kit: $114; Carriers: $355/package. Cable: $0.39/foot	S	Under pavement (inserted in a 3-inch non-metallic conduit placed 21±3inch under the roadway)
SPVD	$395/unit Receiver: $225 - $625/unit Battery: $39.95/unit	S	Under pavement (core drilling an 8 inch hole or using a jack hammer to cut a 6 inch square by 8 inch in depth)
Active Infrared			
Autosense II	$6000-$7500/unit	S	O (20 – 25ft)
Passive Infrared			
ASIM IR	IR 224: $1300/unit	S	O (18 ft)
	IR 254: $700/unit	S	O/S (13-33 ft)
Siemens PIR-1	$1100/unit	S	O (18 ft)
Eltec Model 842	$1360/unit	S	O/S
Microwave Radar			
Accuwave 150LX	$975; An interface panel for two detectors: $150	M	O
RTMS	$3300/unit	M (8 separate detection zones)	O (17-22 ft) S (> 17 ft)
TC 26B	$735/unit	M	O (14-18ft) S (14-18 ft, near the immediate area adjacent to desired coverage area)

TDN-30	$995/unit	S	O
Loren	?	M (4 lanes)	S (19-39 ft)
Ultrasonic			
Lane KingTM	?	Single/Dual (2 separate detection zones)	O (28 ft) S (12-18 ft)
TC 30	$475/unit	S	O (12-18 ft) S (3-5 ft)
Passive Acoustic			
SmartSonic TSS-I	$5000/unit; A controller card for four sensors: $800.	S	S
SmarTek SAS – I	$3500/unit	M (5 lanes)	S (25-40 ft)
Video Image Processing			
Autoscope	Autoscope solo (2) - Single direction: $4900 Entire intersection: $18000	M (32) (5)	O/S
	Autoscope 2020 (replacing 2004) – Single direction: $4820 Entire intersection: $23000		
VideoTrak	$14000/VIP processor; Camera, cable, housing, cable: $1700 (3)	M (32) (5)	O (recommended) S (possible not good as O)
Traficon	$4000 per camera (camera, VIP, housing, lens, cables, surge protection, set-up and training) (4)	M (24) (5)	O/S (25-45 ft)

Note:
Prices listed here may change, and the vendor-authorized dealers should to be contacted for a final price.
(1) – The price of JARMAR TRAX-II
(2) – Autoscope solo includes a camera and a processor
(3) – Recommended camera is a Our Philips BW camera with integrated IR filter. Use of non-recommended camera may introduce optical artifacts that reduce system performance.

(4) – A high resolution CCD black/white or color camera. The video camera should provide detailed video without lag, image retention, or geometric distortion.
(5) – Maximum number of detection zones per camera
S – Single-lane detector, M – Multiple-lane detector, O – Overhead, S – Sidefire.

Table 7: Roadside Detection Operation and Maintenance Costs

Detector Technology	Operation/Maintenance ($K/year)		Notes
	Low	High	
Inductive loop on corridor	0.5	0.8	Double Set (four loops) with controller, power, etc.
Inductive loop at intersection	1	1.6	Four legs, two lanes/approach
Video image processing on corridor	0.2	0.4	One sensor both directions of travel
Video image processing at intersection		0.2	Four-way intersection, one camera per approach
Passive acoustic on corridor	0.2	0.4	Cost range is for a single sensor covering up to five lanes.
Passive acoustic at intersection	0.2	0.4	Four sensors, four leg intersection
Remote Traffic Microwave Sensor on corridor		0.1	One sensor both directions of travel
Remote Traffic Microwave Sensor at intersection		0.1	Four sensors, four leg intersections

Note: the operation/maintenance costs could be similar for devices with similar difficulties of installation and calibration.

Source: ITS Unit Costs Database (13)

Table 8: Device Cost, Installation Cost and System Life of Detector Technologies

Technology		Unit Device cost	Installation cost (1) (2) ($/unit)	System Life (year) (3)
Inductive loop		■	(7)	5 – 15 (4)
Magnetic		■	(8)	15 (5)
Active infrared		◩/□	$200	7
Passive infrared		■/◩	$200	7
Microwave radar	Doppler	■	$200	7
	True Presence	■/◩		
Ultrasonic		■	$200	7
Passive acoustic		◩	$400-$500	7
VIP		□	$1000 - $1500 (6)	10

Note: (1) – Traffic control cost is not considered. Traffic control for a single lane closure can be $1000 - $1500/hr in large urban areas. Intrusive detectors and non-intrusive detectors with overhead installation may require traffic control.
(2) – Installation costs are estimated values, taken from the report, “Vehicle Detection Workshop” by Dan Middleton and Rich Packer.
(3) – It is difficult to decide system life for most detector technologies since they were only applied for a short period. The data in the table is average system life, based on ITS Unit Costs Database (13) and vendor survey results.
(4) – The average failure rate of inductive loops within a district decides the average system life.
(5) – SPVD requires replacing the battery to renew the life every four years.
(6) – Staff time to setup and calibrate a six-lane freeway system is estimated to be $1000 - $1500. Other material costs are included in the unit cost of VIP systems shown in Table 6.
(7) – Installation cost of an inductive loop is included in the unit device cost in Table 6.
(8) - According to the survey on Brian Hagan, State of Idaho Transportation Department, on four highway sites with a total of 16 lanes and 32 probes, the total cost of 3M microloops is $35000, including devices and installation.
? – unknown, ■ – Low (< $1000), ◩ – Medium ($1000 – $2500), □ – High (> $2500).

Table 9: Error Rates of Detector Devices in Freeway Field Tests

Sensor	Mounting Location	Count	Speed	Evaluation Organization
		1. Inductive loop		
Saw-cut	Pavement	3%	1.2% - 3.3%	MNDOT (1)
Saw-cut	Pavement	2%	5%-10%	TTI (8)
Preformed	Pavement	2%	2% - 5%	TTI (8)
		2. Magnetic		
3M microloop	Pavement	2.5%	1.4% - 4.8%	MNDOT (1)
3M microloop	Bridge	1.2%	1.8%	MNDOT (1)
3M microloop	Pavement	5%	μ : -0.25 mph σ : 3.6 mph	TTI (3)
SPVD	Pavement	1% (Phoenix) 10%-12% (Florida)		HAC (4)
		4. Active Infrared		
Autosense I	Overhead	2.4%		MNDOT (2)
Autosense II	Overhead	0.7%	5.8%	MNDOT (1)
		5. Passive Infrared		
ASIM IR 224	Overhead	1%		MNDOT (2)
ASIM IR 254	Overhead	10.0%	10.8%	MNDOT (1)
Siemens PIR - 1	Overhead	10%		TTI (8)
		6. Microwave Radar		
Accuwave 150LX	Overhead	10%		TTI (8)
TDN 30	Overhead	2.5% - 13.8%	1%	MNDOT (2)
RTMS	Overhead	2%	7.9%	MNDOT (2)
RTMS	Sidefire	5%		MNDOT (2)
RTMS	Sidefire	3% - 5%		ODOT (6)
RTMS	Sidefire	3%		SDDOT (5–10)
RTMS	Sidefire	2.4% - 13.6%	2.6% - 5.9%	TTI (9)
		7. Ultrasonic		
TC 30	Overhead	2%		MNDOT (2)
Lane King	Overhead	1.2%		MNDOT (2)

8. Passive Acoustic				
SAS – I	Sidefire	8% - 16%	4.8% - 6.3%	MNDOT (1)
SAS – I	Sidefire	4.0% - 6.8%	3.4% - 4.8%	TTI (9)
SAS – I	Sidefire	10%	μ : -0.5 mph σ : 4.8 mph	TTI (3)
Smartsonic TSS-1	Overhead	4%		MNDOT (2)
Smartsonic TSS-1	Overhead	15%	μ : 4 mph	TTI (8)
9. Video Image Processing				
Autoscope 2004 (1)	Sidefire	5%	Difference range: 5mph	ERAU (5)
Autoscope 2004	Overhead	2.2% - 10.6%		MNDOT (2)
Autoscope solo	Sidefire	5%	8%	MNDOT (1)
Autoscope solo	Overhead	5%	2.5% - 7%	MNDOT (1)
Autoscope solo	Sidefire	2.1% - 3.5%	0.8% - 3.1%	TTI (9)
VideoTrak 900 (1)	Overhead	1.6% - 4.8%		MNDOT (2)
VideoTrak 900	Sidefire	10%	μ : +1.4 mph σ : 6.9 mph	TTI (3)
Traficon	Sidefire	5% (45 feet) 10% - 15% (25 –30 feet)	2% -12%	MNDOT (1)
Traficon	Overhead	2.7% - 4.4%	3% - 7.2%	MNDOT (1)
Traffic Vision		1.8% - 4.8%		TTI (8)

Note: The results in the table represent the tests under optimal operating conditions.
(1) – Autoscope 2004 is being replaced by the new vision Autoscope 2020; VideoTrak 900 is being replaced by the new vision.
μ – mean, σ – standard deviation.
MNDOT – Minnesota Department of Transportation, TTI – Texas Transportation Institute, ERAU - Embry-Riddle Aeronautical University, SDDOT – South Dakota Department of Transportation.

Table 10: Error Rates of Detector Devices in Intersection Field Tests

Sensor	Technology	Mounting Location	Count	Evaluation Organization
Saw-cut	Inductive loop	Under pavement	3% - 9%	MNDOT (1)
Eltec Model 833	Passive infrared	Overhead	15%	MNDOT (2)
TC 30	Ultrasonic	Overhead	> 10%	MNDOT (2)
Lane King	Ultrasonic	Overhead	20%	MNDOT (2)
SAS-I	Passive Acoustic	Sidefire	0% for presence	MNDOT (1)
Smartsonic TSS-1 [(1)]	Passive Acoustic	Overhead	10%	MNDOT (2)
Autoscope solo	VIP	Overhead	18% in right turn lane, 19% in through lane	MNDOT (1)
Traficon [(2)]	VIP	Overhead	17% in right turn lane, 13% in through lane	MNDOT (1)
Vantage	VIP	Overhead	19% for non-proper actuation of signal phases, 8.3% for false detection.	CPSU (11)
RTMS	Microwave	Sidefire	Could detect the arrival of vehicles approaching the intersection as the inductive loops did	CUNY (14)
Autoscope, Vantage, VideoTrak, and Traficon [(3)]	VIP	Overhead/ Sidefire	The average discrepancy call frequency is 5.3 calls/cycle and the error rate is about 1.8. The average duration of discrepant calls was about 2.1 seconds/call. During about 20% of the signal cycles, a phase experienced 4.1 missed or unneeded calls, and the total duration of these calls averaged 24.6 seconds per cycle.	TTI (15)

Note: (1) – Manual observations revealed that the device missed and double counted vehicles and that the daily results compensated errors.
(2) – The vendor indicated that a different VIP card is designed for use in intersection applications and that the results would be improved by using this card.
(3) – Discrepant calls refer to those calls that have discrepancy between the phase-call information provided by the VIPs and the true call information provided by a perfect detector. The discrepant call frequency is the number of discrepant calls per signal cycle and the error rate is the ratio of discrepant calls to true calls.
MNDOT – Minnesota Department of Transportation, TTI – Texas Transportation Institute, CPSU - California Polytechnic State University, CUNY - City University of New York.

Table 11: Detection Performance on Freeways

Detector Technology		Count Accuracy		Speed Accuracy	Classification Accuracy (1)	Environmental Effect
		Low Volume	High Volume			
Inductive loop		■	■	◩	◩	■
Magnetic		■	■	■	?	■
Pneumatic road tube		◩	□	□	?	◩
Active infrared		■	■	◩	■	◩
Passive infrared		◩	◩	□	□	■
Radar	Doppler	■	◩	■	□	■
	True presence	■	■	◩	◩	■
Passive acoustic		◩	◩	■/◩	□	□
Pulse ultrasonic		■	■	□ (2)	□	■
VIP		■	■	◩	□	□

Note:
■ = Excellent (< 5%); ◩ = Fair (< 10%); □ = Poor (> 10%); ? = Unknown
(1) – The classification accuracy rate refers to the project report: “Evaluation of Some Existing Technologies for VehicleDetection” (10).
(2) – Referred to (10).

Table 12: The Impacts of Environmental and Traffic Factors on the Performance of Detector Technologies

Detector Type		Environmental Impact				Traffic	
		Penetration	Wind	Temperature (1)	Light	High volume	Low volume
I	Inductive Loop	✓ (2)	✓	×	✓	✓	✓
	Magnetic	✓ (2)	✓	✓	✓	✓	✓
	Pneumatic Road Tube	✓ (2)	✓	×	✓	×	✓
N	Active Infrared	×	✓	✓	✓	✓	✓
	Passive Infrared	✓	✓	✓	✓	✓	✓
	Microwave	✓ (3)	✓	✓	✓	× (4)	✓
	Ultrasonic	✓	✓	✓	✓	✓	✓
	Passive Acoustic	×	✓	×	✓	×	✓
	Video Image Processing (5)	×	×	×	×	✓	✓

Note: × - affected, ✓ - not affected
(1) The temperatures are extremely low or high and each detector device has its own operating temperature range.
(2) They may possibly be damaged by snow removal equipment.
(3) The RTMS vendor mentions that rain and snow smaller than ten millimeters should not hinder detection capabilities.
(4) Doppler microwave is not good at stop-and-go conditions.
(5) VIP systems are incorporating a variety of new features to reduce the impacts of environmental factors on detection accuracy, such as image stabilization algorithm, sun location algorithm, night reflecting algorithm, contrast loss detector, and advance detector.

Table 13: The Ease of Installation and Reliability of Detector Devices

Technology/Sensor	Ease of installation	Ease of calibration	Reliability [2]
Inductive loop	□	■	■
Magnetic			
3M Microloop	□	◩	■
SPVD	□ [3]	◩ [3]	■ [3]
Pneumatic Road Tube	◩ [3]	■ [3]	◩ [3]
Active infrared			
Autosense I	■	■	◩
Autosense II	◩	■	■
Passive infrared			
Eltec Model 833	■	■	◩
ASIM IR 224	■	■	◩
ASIM IR 254	■	◩ [1]	■
Semens PIR-1	?	?	?
Microwave			
TC-26 B	■	■	?
TDN-30	■	■	◩
ECM Loren	◩	□	□
Accuwave 150LX	?	?	?

RTMS	■	◩	◩
Ultrasonic			
Lane King	■	◩	■
TC-30	□	■	◩
Passive acoustic			
SmarTek SAS-1	■	■	■
Smartsonic TSS-1	■	□	■
VIP			
Autoscope 2004 **(4)**	□	□	■
Autoscope Solo	■	◩	■
VideoTrak 900 **(4)**	□	□	◩
Traficon	■	◩	■
Vantage	?	?	?

Note:

■ Denotes a sensor that performed satisfactorily in the stated condition.

◩ Denotes a sensor that meets some but not all the criteria for satisfactory performance in the stated condition.

□ Denotes a sensor that does not perform satisfactorily in the stated condition.

? Denotes a situation that could not be confirmed.

(1) – ASIM IR 254 was difficult to calibrate for sidefire installation because of alignment complications.
(2) – Reliability level is based only on the performance shown in the tests.
(3) – The evaluation is based on the information from survey responses or experience.
(4) – Autoscope 2004 is being replaced by the new vision Autoscope 2020; VideoTrak 900 is being replaced by the new vision.

Source: MNDOT tests (1, 2)

Table 14: Ease of Installation and Maintenance of Detector Technologies

Detector Technology		Ease of Installation	Ease of Calibration	Maintenance Requirement (2)
Inductive Loop		□	■	□
Magnetic		◩	◩	?
Pneumatic Road Tube		■	■	/
Active Infrared		■	■	■
Passive Infrared		■	■/□ (1)	■
Microwave Radar	Doppler	■	■	◩
	True Presence	■	■	■
Passive Acoustic		■	■	■/◩
Ultrasonic		■	■	■
VIP		■	□	◩

Note: ■ – Excellent/Low, ◩ – Fair/Medium, □ – Poor/High,
? – unknown, / - inapplicable.
(1) – Sidefire installation is difficult because of alignment complications
(2) – The maintenance requirement refers to the project report: “Evaluation of Some Existing Technologies for Vehicle Detection” (10)

Table 15: Estimated Life-cycle Costs for a Typical Freeway Application

Detector Device	Device		Installation		Annual Maintenance Cost	System Life (Year)	Life-Cycle Cost (per system)
	Unit Quantity	Cost	Mounting	Cost			
Inductive loop	12 loops	$9000 (1)	/		$700	5	$2720
						15	$1510
3M Microloop	$13125(2)				$200	15	$1380
Autosense II	6 Autosense II	$36000	O	$3200 (3)	$600	7	$7130
ASIM IR 254	6 ASIM IR 254	$4200	O	$3200 (3)	$600	7	$1832
			S	$1200			$1500
Siemens PIR-1 (4)	6 Siemens PIR-1	$6600	O	$3200 (3)	$600	7	$2230
RTMS	One unit per direction	$6600	O	$2400 (3)	$200	7	$1700
			S	$400			$1370
TC 26B	One unit per direction	$1470	O	$2400 (3)	$200	7	$850
			S	$400			$510
TDN 30	6 TDN 30	$5970	O	$3200 (3)	$600	7	$2130
SmarTek SAS-1	One unit per direction	$7000	S	$800	$400	7	$1700
Autoscope solo	One camera per direction	$9800	O	$3000 (3)	$400	10	$1980
			S	$1000			$1730
VideoTrak 900	One camera per direction	$17400	O	$3000 (3)	$400	10	$2920
			S	$1000			$2670
Traficon	One camera per direction	$8000	O	$3000 (3)	$400	10	$1760
			S	$1000			$1510

Note: A typical freeway location has two directions, and three lanes at each direction. Data needs are traffic count and speed.
Cost information is based on Tables 6, 7 and 8.
1. The average loop cost is $750, including installation cost.
2. According to the survey on Brian Hagan, State of Idaho Transportation Department, on four highway sites with a total of sixteen lanes and thirty-two probes, the total cost of 3M microloops is $35000, so the estimation cost including devices and installation of six lanes and twelve probes is calculated proportionately.
3. Overhead installation considers traffic control, assumed as $1000 per direction.
4. Siemens PIR-1 cannot provide speed data.

Table 16: Estimated Life-cycle Costs for a Typical Intersection Application

Detector Device	Device		Installation Cost		Annual Maintenance Cost	System Life (Years)	Life-Cycle Cost (per system)
	Unit Quantity	Cost					
Inductive loop	32 loops, 3 loops for one through lane, and 2 loops for one left turn pocket	$24000	/		$1300	5	$6700
						15	$3460
SPVD	16 SPVD detectors, 16 batteries, 4 receivers, 1 pole mounted antenna, 1 receiver multi-coupler	$9700	$12000 (3)		$360 (1)	15	$2310
ASIM IR 254	12 ASIM IR 254	$8400	O	$6400 (2)	$200	7	$2670
			S	$2400			$2000
Siemens PIR-1	12 Siemens PIR-1	$13200	$6400 (2)		$200	7	$2800
Eltec Model 842	12 Eltec Model 842	$16320	O	$6400 (2)	$200	7	$4000
			S	$2400			$3320
RTMS	4 RTMS	$13200	O	$4800 (2)	$100	7	$3100
			S	$800			$2440
TC-30	12 TC30	$5700	O	$6400 (2)	$200	7	$2220
			S	$2400			$1550
SmarTek SAS-1	4 SmarTek SAS-1	$13000	S	$1600	$300	7	$2740
Autoscope solo	4 Autoscope solo	$18000	O	$8000 (2)	$200	10	$3400
			S	$4000			$2920
VideoTrak 900	4 cameras	$20800	O	$8000 (2)	$200	10	$3750
			S	$4000			$3260
Traficon	4 cameras	$16000	O	$8000 (2)	$200	10	$3160
			S	$4000			$2670

Note:
A typical intersection has four approaches, with two through lanes and one left-turn pocket at each approach. The signal phases are four phases, with two through phases and two left-turn protected phases.
Cost information is based on Tables 6, 7 and 8.
1. Including battery replacement every four years.
2. Overhead installation considers traffic control, assumed as $1000 per approach.
3. It is estimated at $3000 per approach.

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